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published in

Infant Behavior and Development
2018

DOI (link to publisher)

[10.1016/j.infbeh.2018.07.004](https://doi.org/10.1016/j.infbeh.2018.07.004)

document version

Publisher's PDF, also known as Version of record

[Link to publication in VU Research Portal](#)

citation for published version (APA)

Aktar, E., Mandell, D. J., de Vente, W., Majdandzic, M., Oort, F. J., van Renswoude, D. R., Raijmakers, M. E. J., & Bogels, S. M. (2018). Parental negative emotions are related to behavioral and pupillary correlates of infants' attention to facial expressions of emotion. *Infant Behavior and Development*, 53, 101-111.
<https://doi.org/10.1016/j.infbeh.2018.07.004>

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Full length article

Parental negative emotions are related to behavioral and pupillary correlates of infants' attention to facial expressions of emotion



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ARTICLE INFO

Keywords:

Pupillometry

Attention

Infancy

Emotion

Parents

Depression

Anxiety

ABSTRACT

Previous evidence revealed links between maternal negative emotions and infants' attention to facial expressions of emotion in clinical and community samples. This study investigated the associations between infants' attention to emotional faces and infants' and parents' negative emotions in a community sample. Infants' ($N = 57$, $M_{\text{age}} = 14.26$ months) fixations and pupil responses to fearful, sad, angry versus happy and neutral faces were measured with an eye-tracker. Mothers' and fathers' negative emotions (negative affect, depression, and anxiety), and infants' negative temperament were measured with questionnaires. Infants looked longer at fearful than happy or neutral faces, while they showed less pupil dilation to fearful than to happy or neutral faces. Higher levels of maternal negative emotions were related to less pupillary arousal to emotional facial expressions in infants, while paternal negative emotions did not predict infants' pupil responses. Exploratory analyses suggested a significant link between paternal but not maternal negative emotions and infants' fixations that was moderated by infant negative temperament: Higher levels of negative emotions in fathers were related to longer fixations in children with high levels of negative temperament, while it was related to shorter fixations in infants with low levels of negative temperament. The findings provide support for the idea that exposure to mothers' and fathers' negative emotions play a role on the development of infants' attention to facial expressions in typical development.

1. Introduction

Faces convey information about potential threats in the environment. Attending to facial expressions of conspecifics is therefore advantageous for survival. Emotional brain systems responsible for face processing develop rapidly after birth (Leppänen & Nelson, 2009; Leppänen, 2011; Slater et al., 2010). Exposure to faces in the environment plays a crucial role in this development (Leppänen, 2011). The most prominent facial input in infants' early environment is parents' faces. Typically developing infants are predominantly exposed to positive expressions from parents in every day face-to-face interactions (Aktar, Colonnese, de Vente,

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<https://doi.org/10.1016/j.infbeh.2018.07.004>

Received 4 March 2018; Received in revised form 21 July 2018; Accepted 29 July 2018

Available online 20 August 2018

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Majdandžić, & Bögels, 2017). Theories of early emotional development assign an important role to infants' exposure to caregivers' positive affect for the development infants' expression and regulation of emotion in early interactions (Aktar & Bögels, 2017; Lavelli & Fogel, 2013; Murray et al., 2016).

1.1. Attention biases to threat in typical development and psychopathology

Depression and anxiety are highly prevalent conditions in early years of parenthood that are, by definition, linked to a decrease in the experience and expression of positive emotions (Reck et al., 2008; Ross & McLean, 2006). The presence of depression and/or anxiety in parents increases the risk of psychopathology in the offspring (Beardslee, Gladstone, & O'Connor, 2011; Hettema, Neale, & Kendler, 2001). Regarding attentional processes, childhood and adulthood forms of depression and anxiety are characterized by enhanced attention to negative stimuli (Leppänen, 2006; Roy et al., 2008; Van Bockstaele et al., 2014). Cognitive theories of depression and anxiety assign attention biases to threat in depression and anxiety a causal role in the development and maintenance of these disorders (Beck & Clark, 1988; Beck & Haigh, 2014).

Interestingly, this maladaptive pattern of attention biases towards threat is part of typical emotional development in infancy. Between 5 and 7 months of age, typically developing infants start to pay more attention/show more interest to facial expressions of threat (fear and angry) than happy faces (Peltola, Leppänen, Palokangas, & Hietanen, 2008; Peltola, Leppänen, Mäki, & Hietanen, 2009; Peltola, Hietanen, Forssman, & Leppänen, 2013; Leppänen & Nelson, 2012; Vaish, Grossmann, & Woodward, 2008). Infants' prominent exposure to positive facial expressions by the parents in early months of life is suggested to be important for the emergence of this attention bias to threat (see Vaish et al., 2008). Infants' biased processing of faces that signal threat is advantageous for their survival at this period as they start to increasingly move away from the parent with the onset of crawling and walking (Campos et al., 2000; Clearfield, 2011). However, in cases where it is preserved over time, this bias towards threat in infants' attention may lay the foundation for later maladaptive developmental pathways (Field & Lester, 2010; Leleu, Douilliez, & Rusinek, 2014; Morales, Fu, & Pérez-Edgar, 2016).

1.2. Links of infants' attention to infant temperament, and to parental negative emotions, depression and anxiety

Earlier evidence suggests that the typical/non-clinical variation in parents' negative emotion, depression and anxiety may be related to infants' attention biases towards threat. Rather than being solely determined by infants' environment, the development of attention biases in typical and atypical development result from the joint influences between infant characteristics and environmental experiences (including parental negative emotions, depression and anxiety, Leppänen, Cataldo, Enlow, & Nelson, 2018; Morales et al., 2016). Infants' temperament is a biologically based index of infants' expression/regulation of their own emotions as well as what they look for, or perceive as salient in the environment (Rothbart, 2007). Links were reported between infants' negative temperament and the threat-bias in infants' attention (De Haan, Belsky, Reid, Volein, & Johnson, 2004; Martinos, Matheson, & De Haan, 2012; Nakagawa & Sukigara, 2013). Infants with more negative temperament have more difficulty in disengaging from fearful faces, thus show a more pronounced attention bias for fear at 12 months (Nakagawa & Sukigara, 2013). Differential susceptibility models suggest that infants with negative temperamental dispositions are more susceptible to the effects of the environment, such that these infants would be the ones who are most vulnerable to environmental adversity, and who profit the most from a positive environment (Belsky & Pluess, 2009).

A small number of studies considered the joint influence of infants' negative temperament and parents' negative emotions in typically developing infants' attention biases. First, in an ERP study, De Haan et al. (2004) found that infants with fearful temperament show a more pronounced bias to fearful faces in their ERP responses. Parents' negative affect, did not significantly predict 7-month-olds ERP responses or attention to fearful (vs. happy) faces, neither alone, nor in interaction with child fearful temperament in this study. Second, Aktar and colleagues (Aktar et al., 2016) found that infants with higher levels of sad temperament show more pupillary arousal to negative and positive (vs. neutral) facial expressions. This study also tested the links between parents' anxiety/depression/ negative affect and child attention to emotional facial expressions, and the moderation of these links by temperament, but these were not significantly linked to infants' attention. Third, Morales et al. (2017) tested the links of infants' temperamental negative affect and maternal anxiety to infants' attention to angry vs. neutral faces at 4-to-24-month-olds. This study revealed an attentional bias towards anger: infants disengaged slower from angry than neutral faces. Infants' temperamental negative affect did not significantly relate to infants' attention bias to threat, neither alone nor in interaction with maternal anxiety, while infants of mothers with more anxiety were slower to disengage from angry faces, revealing a positive association between anxiety in mothers and attention biases to threat (angry vs. neutral).

The goals of the current study are two-fold: The first is to investigate behavioral and physiological correlates of typically developing infants' attention to positive and negative (vs. neutral) facial expressions, and the second is to examine the links of infants' negative temperament, and parents' emotions to infants' attention to emotional facial expressions in a community sample.

1.3. Measuring attention using eye-tracking

Eye-tracking methods have increasingly gained popularity in the last decade in infant studies of attention to emotional stimuli (Geangu, Hauf, Bhardwaj, & Bentz, 2011; Gredebäck, Eriksson, Schmitow, Laeng, & Stenberg, 2012; Jessen, Altvater-Mackensen, & Grossmann, 2016). This tool provides a unique opportunity to simultaneously address the physiological and behavioral components of infants' attention (that is, looking behavior and pupil dilation) in a minimally intrusive way. Under stable luminance, pupil dilation

is an index of cognitive and emotional load, and is observed in response to positive and negative (vs. neutral) images in adults (Bradley, Miccoli, Escrig, & Lang, 2008). Pupil dilation resonates the activity of the autonomic nervous system (Bradley et al., 2008; Hepach & Westermann, 2016) and of the limbic system (Siegle, Steinhauer, Stenger, Konecky, & Carter, 2003).

In addition to infants' looking behavior, the current study used pupil dilation as a physiological index of arousal, attention, and interest to emotional stimuli both in infants (Bradley et al., 2008; Hepach & Westermann, 2016; Partala & Surakka, 2003). Earlier pupillary studies in infants revealed inconsistent results: Gredebäck et al. (2012) found that 14-month-old infants who are being raised by both parents show more dilated pupils to fearful (vs. neutral) but not to happy (vs. neutral) faces. In turn, all infants more often fixated on fearful than happy or neutral faces. Aktar et al. (2016) reported more pupil dilation to 1 s presentation of fearful and sad facial expressions in 14-to-17-month-olds. In contrast to these studies, Jessen et al. (2016) recently showed a positivity bias in pupillary responses and fixations: infants had more dilated pupils and longer fixations to happy than to fearful expressions. The discrepancies in findings may be related to the differences in the experimental designs, studied age groups and the stimuli. The current study investigates infants' pupillary responses and fixations to emotional (vs. neutral) facial expressions. The links between infants' attention to facial expressions and parents' negative emotions, depression and anxiety, as well as children's temperament are for the first time investigated using both pupillary responses, and fixations in the current study. Recent evidence revealed links between pupillary responses to emotional expressions and depression and anxiety levels in children and adults. For example, adults with anxiety respond with stronger pupil dilation to angry facial expressions (Kret, Stekelenburg, Roelofs, & de Gelder, 2013), and 9-to-13-year-old children with anxiety disorders show stronger pupil dilation to fearful expressions (Price et al., 2013). Moreover, significant links were shown between parents' depression and/or anxiety and child pupillary responses to negative facial expressions: A study by Burkhouse, Siegle, and Gibb, (2014) found that children of depressed parents show stronger pupil responses to sad facial expressions whereas children of anxious parents show stronger pupil responses to fearful facial expressions.

1.4. Inclusion of fathers in the study of infant attention

As it becomes clear from reviewed studies, the available evidence has mainly come from mothers, while the links between infants' exposure to fathers' emotions and their attention to emotion remain barely explored. Evolutionary theories of parenting not only propose that fathers are as important as mothers, but also assign fathers a differential role in the development of anxiety due to their evolutionarily expertise in dealing with the external world and with strangers (Bögels & Perotti, 2011; Bögels & Phares, 2008). Although this idea awaits to be explored in infancy, and in the attention domain, it is clearly important to start including fathers in the investigation of infants' emotion processing. The current study examined the link between both fathers' as well as mothers' negative affect, depression and anxiety and attention, and pupillary arousal in infancy.

1.5. Current study and hypotheses

In the current study, we investigated the links between 12-to-16-month-old infants' exposure to maternal and paternal negative emotions and their attention to facial expressions of emotion in a community sample. The current age group was of special interest as infants' understanding of facial expressions, and the threat-related attention bias was suggested to become more 'robust' at the end of the first year (Vaish et al., 2008). Moreover, between 10 and 14 months, infants are known to develop the skill to use others' negative emotional reactions to determine whether a novel stimulus is safe or a potential threat (Aktar, Majdandžić, de Vente, & Bögels, 2013; Feinman, 1982). 12-month-old infants change their reactions more strongly when others react negatively (vs. positively) to a novel stimulus (Vaish et al., 2008).

The current study made use of eye-tracking technology to simultaneously capture infants' attention processes on the behavioral level using fixations, and on the physiological level using pupil dilation. The typical non-clinical variation in mothers' and fathers' self-reported negative affect, depression and anxiety was utilized as indirect indices of infants' exposure to negative emotions in this community sample. Based on previous evidence revealing a specific bias in infants' looking preferences to fearful and angry expressions, we expected that the duration of infants' fixations would be longer during fearful and angry (versus neutral) stimuli. Based on previous evidence in adults (Bradley et al., 2008), and in infants (Gredebäck et al., 2012), we expected more pupil dilation in response to negative (vs. neutral) stimuli. In the light of earlier findings on the links between infants' attention to emotional expressions, and parents' negative emotion, depression, anxiety and infants' negative temperament (Aktar et al., 2016; De Haan et al., 2004; Martinos et al., 2012), we expected significant positive associations between infants' attention to facial expressions and parents' negative emotions, and between infants' attention to faces and infant negative temperament. We also explored the moderating role of infant negative temperament for the first time for fathers' together with mothers' negative emotions using both fixations and pupil dilation as outcomes in the current design. Based on differential susceptibility models, one would expect that attention of infants with higher levels of temperamental negative affect would be more susceptible to exposure to parents' negative emotions such that there would be a stronger positive link between infants' attention bias and parents' negative affect, depression and anxiety for infants who have higher levels of temperamental fear, sadness and anger. Based on evolutionarily models of parenting, we hypothesized that fathers' negative affect, depression and anxiety will differentially predict infants' attention, over and above mothers' negative affect, depression and anxiety.

2. Method

This study was approved by the ethical committee of the University of Amsterdam. Participating families were part of a larger

Table 1
Sample characteristics.

| | | Mother (N = 52) | Father (N = 50) |
|-------------------------------------|------------------------|---------------------|---------------------|
| Age <i>M (SD, range)</i> | | 34.48 (4.08, 26–45) | 37.20 (4.52, 29–50) |
| Dutch origin Parent | | 90.38 % | 86% |
| Dutch origin Grandmother | | 86.54% | 76% |
| Dutch origin Grandfather | | 82.69% | 86% |
| Educational level | Secondary Education | 0% | 4% |
| | Professional Education | 21.15% | 30% |
| | University | 75% | 62% |
| Professional Status | Housekeeper | 11.54% | 0% |
| | Part-time | 59.62% | 28% |
| | Full-time | 23.08% | 60% |
| | Unemployed | 1.92% | 6% |
| Monthly income <i>M (SD, range)</i> | < 1000 euros | 21.15% | 0% |
| | 1000–3000 euros | 30.77% | 22% |
| | 3000–5000 euros | 26.92% | 36% |
| | > 5000 euros | 9.62% | 32% |
| Working hours (per week) | | 25.96 (12.88, 0–50) | 34.69(12.42, 0–60) |

sample recruited via invitation letters sent by the municipality to a random sample of families who recently became parents. The infants were invited to visit the lab with one parent, while both parents were asked to fill in the questionnaires for their own negative affect, depression and anxiety, which were used to measure parents' negative emotions in this study. The parents provided written informed consent for participation.

2.1. Participants

The sample consisted of 57 infants between the ages of 12 and 16 months (23 girls; *M* age = 14.26 months, *SD* = 0.65, range: 12.45 to 15.61, 48 infants visited with their mother). Data from 7 additional infants who participated in the study was missing due to equipment failure, movement and/or fussiness (also see 2.3.1. *Data Reduction*). Of the 57 families that participated with their infant, questionnaire data was fully or partially available from 52 families (52 mothers and 50 mothers). Sociodemographic characteristics are presented in Table 1.

2.2. Materials and procedure

2.2.1. Stimuli

The stimuli were black-and-white photographs (1280 × 1024 pixels) exhibiting happy, fearful, sad, angry and neutral facial expressions (presented in Fig. 1). To avoid the confounding effects of differences in visual properties of different individuals' faces, we presented facial expressions from a single person in this study. Considering that the mothers are mostly the primary caregiver in this period, and that infants who are mainly cared by mothers show more attention to female faces (Quinn, Yahr, Kuhn, Slater, & Pascalis, 2002) we used facial expressions from a female model. A convenience sample of 52 adults (33 females and 19 males, *M* age = 27.29, *SD* = 4.35, range: 19–37) labeled the emotion expressed in each picture. The percentage of participants who labeled the emotion correctly was 96.2% for the happy, 96.2% for the angry, 92.3% for the fearful, and 94.2% for the sad face.

The stimuli were made consecutively in a highly-controlled lab setting to achieve greater control over the differences in luminance between facial expressions, and to avoid confounding effects of light on pupil responses. All the photographs were taken in the same studio with similar light conditions. The contrast, clarity and luminance were further standardized in Adobe Photoshop, along with the size and positions of the face and of the eyes. The remaining variance (due to conversion to a jpg, *M* = 73.46, *SD* = 5.35, range: 65.04 to 79.39) in the mean luminance of the photographs had a weak association with raw pupil scores ($r = -0.04$, $p < 0.001$). The luminance values obtained from Adobe Photoshop were therefore initially added to all the models presented in the result section as a confounding variable. The coefficient and standard error for luminance were estimated as null in the models, thus were redundant and not further considered. In other words, the weak association between luminance and pupil scores disappeared once the repeated and random variance for pupil responses over time are controlled for in the model. We therefore conclude that the



Fig. 1. Angry, fearful, happy, neutral and sad faces used in the experiment.

current findings are unconfounded by luminance artifacts.

2.2.2. Questionnaires

2.2.2.1. Parental negative affect. Both parents completed The Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988). The Negative Affect Schedule consists of 10 negative emotions (e.g., distress, irritability or shame), and measures parents' experience of these emotions in the last two weeks on a five-point scale. Our focus was on the negative emotional dispositions, thus, the Negative Affect Schedule. The scores of negative affect were available from 52 mothers and 50 fathers. The reliability of the Negative Affect Schedule was (Cronbach α 's) 0.87 for mothers and 0.85 for fathers.

Both parents filled in the second edition of the Beck Depression Inventory (BDI-II; Beck, Steer, & Brown, 1996), and the adult version of the Screening for Anxiety Related Emotional Disorders (SCARED-A; Bögels & Van Melick, 2004). The BDI-II is a 21-item questionnaire measuring depressive symptoms, and the SCARED-A consists of 71 items assessing symptoms of anxiety disorders. The depression scores were available from 47 fathers and 48 mothers, and anxiety scores from 47 fathers and 49 mothers. The reliability (Cronbach α s) of the BDI-II was 0.77 for mothers and 0.91 for fathers and of the SCARED-A was 0.91 for mothers and 0.86 for fathers. In the current study, parental scores of negative affect were used to capture the typical variation in non-clinical negative emotions, while anxiety and depression scores were used to capture the variation in clinical forms of negative emotions. Mothers' and fathers' negative affect, depression and anxiety scores were averaged into single variables of maternal and paternal negative emotions in the analyses.

2.2.2.2. Infants' negative temperament. The parent visiting the lab with the infant completed the Infant Behavior Questionnaire Revised (available for 52 infants filled in by 45 mothers and 7 fathers, IBQ-R; Gartstein & Rothbart, 2003). The IBQ-R consists of 191 items measuring 14 dimensions of infants' temperament. Due to their direct link to infants' experience of negative emotions, the fearful, the sad and angry (i.e., distress to limitations) temperament dimensions were of interest for this study. Parents rated the frequency of infants' expressions of fear (e.g., crying, or showing distress), sadness (e.g., becoming tearful and sad) and anger (distress to limitations, e.g., fussing, or distress, and protest) in a number of occasions (e.g., fear while visiting a new place or meeting a stranger, sadness after separation from the caregiver or frustration in care-taking activities) in the last two weeks on a 7-point scale. The reliability (Cronbach α 's) of these scales was 0.85, 0.80, and 0.69 respectively. Infants' scores on fearful, sad and angry temperament were averaged into a general score of infant negative temperament.

2.2.3. Procedure

Infants' fixations and pupil responses were measured via an eye-tracker (Tobii T120) in a dimly illuminated room. Infants were seated in a car seat 60 cm away from the screen. Prior to testing, infants' gaze was calibrated with a 5-point procedure. During the test, the parent sat on a chair behind the infant and was instructed to remain neutral and not intervene unless the infant became fussy.

Before the experimental blocks, the facial expressions were presented once in a test block with a fixed order starting with neutral and ending with the sad expression (not used in the analyses). This test block aimed to give the time to the infant and the parent to get used to the dimly illuminated lab environment and gave the experimenter the opportunity to re-adjust the screen and the eye-tracking device when necessary. The experimental block consisted of 4 blocks of 5 trials. In each block, five facial expressions appeared once in pseudo-random order with the following restrictions: the same emotion could not appear consecutively and all emotions were shown before one was repeated. Each trial started with an attention-getter (a moving chick) followed by 500 ms of blank black screen. Next, the first face was presented for three seconds. An experimenter monitoring infants' attention from another room repeated the presentation of the attention getter when necessary before the presentation of each facial expression. In a pilot task that followed the experiment, the faces were presented in pairs in a fixed-order (not used in the current study).

2.3. Statistical analyses

2.3.1. Data reduction

2.3.1.1. Fixations. Fixations were identified using the data-driven algorithm of Mould, Foster, Amano, and Oakley, (2012) implemented in gaze path package (Van Renswoude & Visser, 2015) in R (R Core Team, 2014). This speed-based algorithm overcomes problems with standard dispersal algorithms, such as correlations between dependent variables and noise levels (Wass, Forssman, & Leppänen, 2014). A duration threshold of 100 ms was used and the velocity threshold was estimated for each individual on each trial separately to control for the influence of noise. Infants with noisier trials, indicated by a large variance in point of gaze, had more conservative thresholds than infants with cleaner trials, $r = .60$, $t(60) = 5.82$, indicating that the algorithm was performing well. Missing sequences between fixations on the same location were interpolated using aggregation, leading to 4885 fixations with a mean duration of 436 ms ($SD = 135$). On average, fixation data were available from 14.00 trials ($SD = 5.31$) for each infant. The duration of the fixations on faces were obtained by summing the durations on the face in each trial.

2.3.1.2. Pupil responses. First, to account for measurement error, outlying pupil measurements ($> |3| SD$) were removed from each infant's distribution of pupil scores. Next, missing observations (missing sequences < 500 ms) were identified and replaced via linear interpolation (see Hepach & Westermann, 2016). Following the interpolation, the pupil data were reduced to observations where the infant was looking at the face and was averaged to 60 observation points with 50 ms intervals in the 3-s time window (i.e., time). Trials in which children looked at the face for at least 500 ms within the 3-s presentation time were included in the analyses. Infants' pupil responses to emotional facial expressions were baselined to pupil size during the 500 ms presentation of black screen preceding

each trial (averaged across 10 observation points with 50 ms intervals) via subtraction. Pupil responses were analyzed following the initial pupillary light reflex (i.e., the last 2 s of 3-s presentation, thus 40 observation points of 50 ms interval were used for analysis). The pupil data was available on average for 13.39 trials ($SD = 5.03$) per infant. To explore the associations between the number of available trials and individual differences, we inspected the zero-order correlations. There was a significant positive association between the number of available trials and fathers' negative affect ($r = 0.33$, $p = .019$ for pupil, and $r = .32$, $p = .023$ for fixations). Thus, there were more trials available when fathers had higher levels of negative affect. To keep as much variance as possible in the models for the investigation of individual differences, we did not exclude any participants based on the overall number of trials where the pupil or fixation data were available. We adjusted our analytic approach accordingly and used multi-level models that are known to accommodate for missing data (Bagiella, Sloan, & Heitian, 2000).

2.3.1.3. Multi-level regressions. The duration of fixations, and baselined pupil responses were the outcome variables of this study and were standardized in all analyses. The fixations were analyzed using two-level multi-level regression models with repeated observations nested in trials (level 1), nested in participants (level 2). Pupil responses were analyzed using three-level multi-level regression models with repeated observations over time within trial (level 1) nested in trials (level 2), nested in participants (level 3). The intercept was randomized in all models, and the effect of time was additionally randomized in the pupil models. The random effects of these variables were significant and retained in all models. The effects of emotion, time, and block were fixed in all models. The neutral expression was used as the reference for emotion in the models (except for the additional models aiming to compare infants' attention to negative vs. positive emotion). Inspection of distributions of residuals indicated sufficient normality in all models (skewness and kurtosis of all residuals were $< |2|$). Maximum likelihood was the estimation method, and an auto-regressive covariance structure was used for repeated effects of trials, and time within trial in the models. All the effects were evaluated at $\alpha \leq 0.05$.

3. Results

3.1. Preliminary analyses

Zero-order correlations between predictor variables did not reveal a significant link between infants' negative temperament, and mothers' or fathers' negative emotion. In contrast, there was a positive association between mothers' and fathers' negative emotions ($r = 0.72$, $p < .001$).

3.2. Main analyses

3.2.1. Infants' attention and pupillary arousal to positive and negative emotions

To answer the question of whether infants' pupillary responses and fixation durations differ between emotional and neutral facial expressions, we first tested an initial model with the main effects of emotion along control variables. The initial multi-level model for duration of infants' fixations and for infants' pupil responses both consisted of the main effects of emotion (i.e., happy, fearful, angry, and sad vs. neutral), and control variables (trial order [0 to 19], and block [0 to 3], and time for pupil dilation [0 to 39]). These models are presented in Table 2 ($n = 57$). Infants' fixations were longer for fearful than neutral faces, while the duration of infants' fixations on happy, sad, and angry faces did not differ from neutral faces. Infants' pupils dilated significantly less from the baseline (i.e., blank screen) for fearful than neutral faces, while infants' pupil responses to happy, sad and angry faces did not differ from neutral faces (see Fig. 2). Infants' pupil response to emotional expressions increased over time.

Table 2

The multilevel-regressions of infants' duration of fixations ($N = 57$), and pupil responses ($N = 57$) on emotion.

| Parameter | Duration of fixations | | | | | | Pupil Responses | | | | | | | |
|---------------------|-----------------------|------|--------|-------|--------|-------------------------|-----------------|-------|------|--------|-------|--------|-------------------------|-------------|
| | β | SE | df | t | p | 95% Confidence Interval | | β | SE | df | t | p | 95% Confidence Interval | |
| | | | | | | Lower Bound | Upper Bound | | | | | | Lower Bound | Upper Bound |
| | | | | | | | | | | | | | | |
| Intercept | −0.21 | 0.12 | 153.18 | −1.72 | .088 | −0.45 | 0.03 | −0.60 | 0.12 | 109.16 | −4.92 | < .001 | −0.84 | −0.36 |
| Order of Trials | 0.01 | 0.02 | 736.00 | 0.49 | .627 | −0.03 | 0.05 | 0.02 | 0.02 | 723.10 | 1.33 | .185 | −0.01 | 0.06 |
| Block | −0.09 | 0.10 | 737.83 | −0.88 | | −0.30 | 0.11 | −0.03 | 0.09 | 722.99 | −0.38 | .705 | −0.20 | 0.14 |
| Happy vs. Neutral | 0.13 | 0.09 | 649.60 | 1.50 | .134 | −0.04 | 0.30 | 0.00 | 0.07 | 728.36 | −0.04 | .970 | −0.15 | 0.14 |
| Fearful vs. Neutral | 0.33 | 0.08 | 629.13 | 3.87 | < .001 | 0.16 | 0.49 | −0.32 | 0.07 | 718.72 | −4.40 | .001 | −0.47 | −0.18 |
| Angry vs. Neutral | 0.04 | 0.09 | 680.35 | 0.43 | .665 | −0.13 | 0.21 | −0.07 | 0.07 | 732.61 | −0.91 | .365 | −0.21 | 0.08 |
| Sad vs. Neutral | 0.09 | 0.09 | 657.84 | 1.00 | .320 | −0.08 | 0.25 | −0.11 | 0.07 | 726.71 | −1.51 | .131 | −0.26 | 0.03 |
| Time | | | | | | | | 0.03 | 0.00 | 55.19 | 11.58 | .001 | 0.03 | 0.04 |

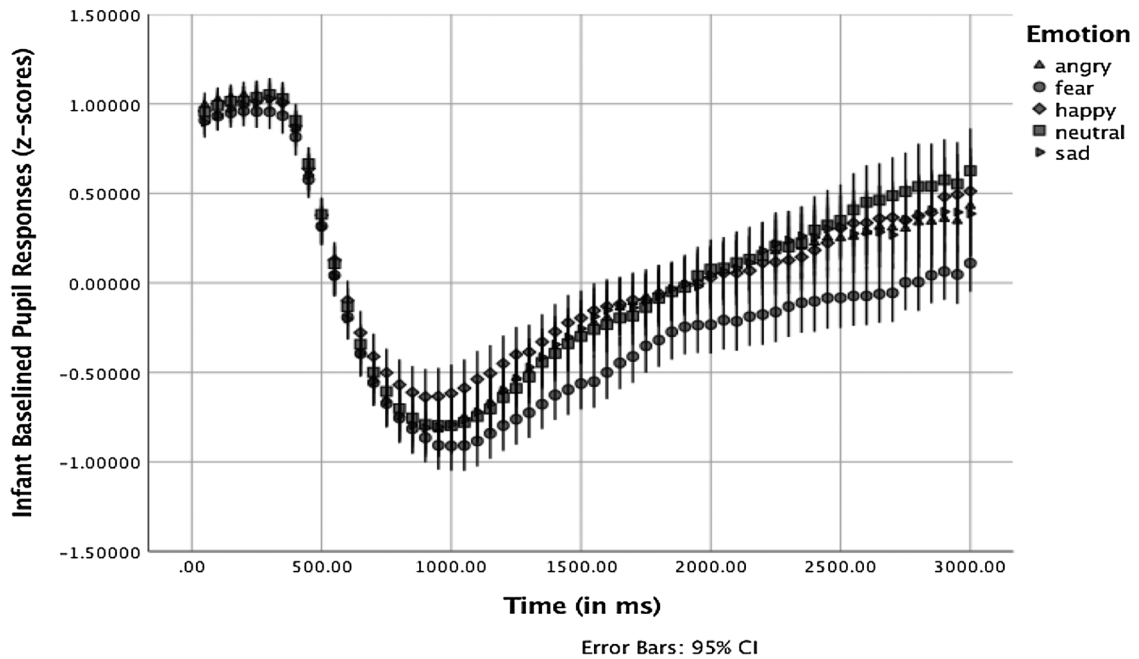


Fig. 2. Infants' standardized baselined pupillary responses (on the y-axis) over stimulus presentation time (on the x axis) in separate lines averaged per emotion.

In view of earlier inconsistencies in the literature, we also analyzed the differences between negative vs. positive emotions in an additional step, by changing the reference to happy faces after excluding the neutral face from the analysis from these initial models. The model for fixations revealed a bias for fearful faces, while the model with pupil responses revealed a positivity bias: Infants fixated longer at fearful than happy expressions ($B = 0.21$, $SE = 0.08$, $p = .013$), while their pupils dilated significantly less during fearful than happy faces ($B = -0.32$, $SE = 0.07$, $p < .001$). In turn, no significant differences were found between infants' fixations or pupil responses to angry, or sad (vs. happy) faces.

To shed light on the inconsistencies in the current findings between infants' fixations and pupil dilation responses, we computed the raw associations between pupil responses and fixation durations. The correlation between fixation durations and the raw scores of infant pupil diameter to faces was significant ($r = -0.28$, $p < .001$), while the association between fixations and the baselined pupil responses, the outcome measure in the pupil analyses, was not significant ($r = -0.01$, $p = .844$).

3.2.2. Individual differences in infants' attention and pupillary arousal to positive and negative emotions

To answer the question of whether individual differences in infants' attention to emotional (vs. neutral) expressions can be explained by infants' temperamental negative affect and/or parents' negative emotions, we conducted a second set of multi-level regression models. This second set of models included infants' negative temperament scores (averaged scores of infants' fearful, sad and angry temperament), and maternal and paternal negative emotions (averaged scores of parental negative affect, depression and anxiety) as continuous predictors. In exploratory analyses, we additionally tested two-way interactions between parental negative emotions and child negative temperament.

In the final model with the duration of fixations as the outcome ($N = 50$), none of the tested main effects were significant, i.e., mothers' negative emotions ($p = .724$), fathers' negative emotions ($p = .839$), and infants' negative temperament ($p = .412$). Thus, parents' negative emotions or infants' negative temperament were not related to the duration of infants' fixations on emotional facial expressions. In an additional exploratory step, we tested the two-way interactions of maternal and paternal negative emotions and infants' negative temperament. This model revealed a significant moderation of the link between fathers' negative emotions and infants' fixations by infant negative temperament ($B = 0.44$, $SE = 0.14$, $p = .004$), while the interaction between mothers' negative emotions and infants' negative temperament was not significant. We plotted this significant interaction using online tools provided by Preacher, Curran, and Bauer, (2006). There was a significant link between fathers' negative emotions and infants' fixations to emotional expressions for children with low ($z < -0.18$) and high ($z < 1.43$) levels of negative temperament, while this link was not significant for infants with moderate levels of negative temperament. Moreover, the association between fathers' negative emotions and infants' fixations were negative for infants low in negative temperament, while it was positive for highly temperamentally negative infants. In other words, highly temperamentally negative infants with more negative fathers showed enhanced interest to emotional faces, while infants with low levels of negativity and with more negative parents showed a reduced interest to faces.

The final model with infants' pupil responses as the outcome is presented Table 3 ($N = 50$). This model revealed a significant main effect of mothers' (but not fathers') negative emotions. Infants of mothers with higher levels of negative emotional dispositions showed less pupillary arousal to emotional (vs. neutral) facial expressions ($B = -0.42$, $SE = 0.17$, $p = .018$), while fathers' negative

Table 3

The multilevel regression of infants' pupil responses on emotion, infants' negative temperament, and parents' negative emotions (N = 50).

| Parameter | β | SE | df | t | p | 95% Confidence Interval | |
|-----------------------------|---------|------|--------|-------|--------|-------------------------|-------------|
| | | | | | | Lower Bound | Upper Bound |
| Intercept | −0.64 | 0.13 | 94.23 | −5.05 | < .001 | −0.89 | −0.39 |
| Order of Trials | 0.03 | 0.02 | 674.82 | 1.61 | .108 | −0.01 | 0.06 |
| Block | −0.06 | 0.09 | 674.20 | −0.72 | .474 | −0.24 | 0.11 |
| Happy vs. Neutral | 0.02 | 0.08 | 677.46 | 0.25 | .800 | −0.13 | 0.17 |
| Fearful vs. Neutral | −0.32 | 0.08 | 670.46 | −4.21 | < .001 | −0.47 | −0.17 |
| Angry vs. Neutral | −0.10 | 0.08 | 683.03 | −1.31 | .189 | −0.25 | 0.05 |
| Sad vs. Neutral | −0.12 | 0.08 | 679.43 | −1.55 | .121 | −0.27 | 0.03 |
| Time | 0.03 | 0.00 | 48.49 | 11.21 | < .001 | 0.03 | 0.04 |
| Infant Negative Temperament | −0.03 | 0.11 | 49.61 | −0.28 | .777 | −0.26 | 0.20 |
| Maternal Negative Emotions | −0.42 | 0.17 | 51.05 | −2.45 | .018 | −0.76 | −0.08 |
| Paternal Negative Emotions | 0.22 | 0.18 | 50.39 | 1.26 | .215 | −0.13 | 0.58 |

emotions did not predict infants' pupillary responses. Exploratory analyses revealed no significant moderation of the links between parents' negative emotions and infants' pupillary responses by infant negative temperament.

In an additional step, we repeated all multi-level models presented in this section after excluding the neutral face, and using the happy face as reference. All significant findings reported above remained significant when infants' attention to negative vs. positive emotions was examined.

4. Discussion

This study investigated infants' fixations and pupillary responses to negative (vs. neutral and positive) faces, and explored the associations of infants' attention to facial expressions of emotion (vs. neutral) with infants' negative temperament, and parents' negative emotions. The findings revealed a mixed/ambivalent pattern of response towards the fearful face: A bias was observed in infants' looking preferences (fixation durations) towards fearful (vs. neutral and happy) expressions, while infants had less dilated pupils (less arousal) during fearful (vs. neutral and happy) facial expressions, indicating a positivity bias. The differences in infants' pupillary responses and fixations were specific to fear, and did not generalize to other threat-relevant (anger) and non-threat-relevant (sad) negative expressions. Infants' pupillary arousal to emotional expressions were predicted by maternal negative emotions, and their interest was predicted by paternal negative emotions. Exploratory analyses suggest that the latter link is moderated by infants' negative temperament. Below we first address the current findings on infants' pupillary arousal and fixations on facial expressions of emotion, and next we turn to the findings concerning individual differences.

4.1. The effect of emotion on fixations and pupil dilation

Current findings revealing longer fixations on fearful than neutral and happy facial expressions are consistent with earlier evidence revealing a bias at 7 and 14-month-old in infants' interest to fearful facial expressions (De Haan et al., 2004; Gredebäck et al., 2012; Kotsoni, de Haan, & Johnson, 2001; Nelson & Dolgin, 1985), and further reveal a fear-specific increase in looking time, that did not hold for facial expressions of anger, and sadness. In contrast to these studies and to the current findings, Jessen et al. (2016) reported longer fixations on happy as compared to fearful facial expressions. We suspect that the inconsistencies in the findings stem from the differences in the presentation time of facial expressions, and in the analyses of pupil response, rather than reflecting age differences. The faces were presented for a much shorter interval in Jessen et al. (2016), i.e., 50 ms in the subliminal, and 950 ms in the supraliminal condition, whereas faces were presented for longer intervals (5 and 3 s respectively) in Gredebäck et al., 2012 and in the current study. Gredebäck et al. (2012) included the entire 5 s presentation in pupil responses, and in the current study where the faces were presented for 3 s, the pupil response was analyzed following the initial pupillary light reflex in the first second of presentation. Taken together, these findings suggest that happy faces may initially attract more attention than fearful faces, while this trend may be reversed after the first second of presentation.

In contrast to the findings by Gredebäck et al., 2012, the current findings revealed a bias for happy than fearful or angry faces in infants' pupillary responses. This is in line with the most recent evidence by Jessen et al. (2016) that also revealed a positivity bias in pupil responses of 7-month-old infants to briefly presented facial expressions of emotion. As mentioned above, a positivity bias was observed also in fixation durations in Jessen et al.'s (2016) study, while no direct association was found between fixation durations and pupil responses. In contrast to this finding, current study revealed that longer fixations were related to less pupil dilation to emotional expressions. Thus, it seems that longer fixations on facial expressions are linked to a decrease in pupillary arousal when the faces are presented for a longer interval. Greater interest (duration of fixation) to the fearful face, accompanied by smaller changes in pupil dilation reveal an inconsistency between behavioral and physiological indices of attention allocation. Similar inconsistencies between behavioral and ERP indices were reported in earlier studies (for example, Field, Pickens, Fox, Gonzalez, & Nawrocki, 1998; Grossmann, Striano, & Friederici, 2007). It was suggested that this mixed/ambivalent response may be related to wariness, or to an empathic response to negative emotions (Field et al., 1998).

The current findings, and the findings by [Jessen et al. \(2016\)](#) are at odds with previous evidence that revealed more pupil dilation to fearful than neutral faces in 14-month-old infants ([Gredebäck et al., 2012](#)). The discrepancies between this latter study and the current findings cannot be explained by age as our findings on pupil dilation matched the positivity bias observed in pupil responses at 7-months, rather than the bias towards fear observed at 14-months. Note that the attentional bias to fearful (vs. happy) faces in the study by [Gredebäck et al. \(2012\)](#) only held for infants cared by both parents. Thus, the fact that the infants in the current sample were predominantly cared by mothers (as revealed by working hours) may explain why this difference did not come out in the current sample. Taken together, the findings suggest that biases to fearful faces may not have fully developed in pupillary responses at this age. Moreover, the differences in infants' looking, and pupil responses observed in the current study was specific to fear and did not generalize to other threat-relevant (i.e., angry) or other negative (i.e., sad) emotions. The lack of attention bias in looking times to angry (vs. neutral and happy) facial expressions is in line with earlier evidence from [LoBue and DeLoache \(2010\)](#), while it is at odds with [Grossman et al. \(2007\)](#) and [Morales et al. \(2017\)](#). The lack of a significant difference in pupillary responses to sad (vs. neutral) is inconsistent with [Aktar et al., 2016](#) who reported more pupil dilation to sad and fearful as compared to neutral faces.

4.2. Individual differences in infants' pupil dilation and fixations to emotions

In line with the idea that infants' exposure to parental emotions plays a role in the typical development of attention to emotional expressions, the current findings revealed significant associations between behavioral and pupillary correlates of infants' attention and parental negative emotions in a community sample. First, more negative emotions in mothers, but not in fathers were related to less dilated pupils, thus less arousal to facial expressions of emotion. Thus, infants who are being exposed to more negative emotions from their mother seem to respond less to emotional facial expressions on the physiological level. In contrast with mothers, fathers' negative emotion did not significantly relate to infants' pupil responses. Interestingly, exploratory analyses suggested a link between fathers' (but not mothers') negative emotion and infants' fixations to emotional faces, moderated by infant negative temperament. Infants with high levels of negative temperament showed more interest to faces, while infants low in temperament showed overall less interest to emotional faces when fathers were more negative. In contrast, mothers' negative emotions were not significantly related to infants' interest. Thus, despite the significant raw correlation between mothers' and father' negative emotions, the current study revealed differential associations for mothers and fathers: More negative emotion in mothers (but not in fathers) seemed to be specifically related to less pupillary arousal, but not to fixations, while more negative emotion in fathers seemed to be related to longer fixations in highly temperamentally negative infants. Current findings provide preliminary support for the idea of a differential susceptibility of temperamentally negative infants to exposure to paternal negative emotion ([Belsky & Pluess, 2009](#)). Considering that enhanced attention to negative emotion is characteristic of information-processing in anxiety disorders ([Van Bockstaele et al., 2014](#)), this increased interest/arousal to emotional stimuli in temperamentally negative infants of more negative fathers may be a risk factor that relates to later development of childhood anxiety disorders and is an important finding that warrants further study. Taken together the findings illustrate the importance of further investigating these links in designs incorporating mothers' and fathers' negative emotions and infant temperament to shed light on the nature of these differences.

The findings of the current study must be interpreted while considering the following limitations. First, using repeated presentations of facial expressions from a single female is not an uncommon practice in infancy research due to infants' relatively limited attention span (e.g., [Nelson & De Haan, 1996](#); [Young-Browne, Rosenfeld, & Horowitz, 1977](#)) and it provides advantages in minimizing the effects of differences in visual properties of different individuals' faces on infants' pupil size and fixations. However, restricted stimulus sampling limits the generalizability of the current findings on infants' attention to other female, and to male faces. The stimuli used in the current study were also not from a standardized database, and were only validated using convenience sampling. Future studies testing the effects of maternal and paternal negative emotions, should consider including more than one exemplar, and both female and male facial expressions from a standardized set. Second, parents' and infants' negative dispositions were indirectly assessed via questionnaires rather than direct observations. Although questionnaires are suitable to assess trait-like measures of negative affectivity, parents' perception of infants' temperament may be biased by parents' own psychopathology ([Najman et al., 2000](#)). Note that the raw associations between parents' negative emotions and infants' negative temperament were not significant in the current sample. Moreover, the temperament was reported predominantly by mothers in this study, as most of the infants visited with mothers. Future studies measuring infants' physiological responses should therefore consider including naturalistic observations of both parents' and infants' emotional expressions as an additional index of parents' negative affect and infants' temperament, in addition to self-report measures. Third, different from the multi-modal and dynamic displays of emotion that infants encounter in everyday life, infants' pupil dilation to emotion was measured with static facial expressions in the current study. Future studies should consider using multi-modal dynamic face displays to test the effects of emotion on infants' emotion processing. Fourth, as compared to adult studies investigating individual differences, the sample size of the current study was small for moderation analyses. As the inconsistencies in the available evidence do not seem to be accounted by age, future studies should consider including a bigger age range (e.g. 7 to 14-months) that will be helpful in achieving bigger sample sizes. Fifth, due to a relatively small sample size resulting in lower power, the findings should be approached with caution before the associations are replicated in a larger sample. Finally, the study had a cross-sectional and non-experimental design, precluding any prospective or causal inference on the effect of parental negative affect, depression, and anxiety, and of infants' temperament on infants' attention to facial expressions. Despite these limitations, the current study provides evidence for significant associations between infants' own negative temperamental negative affect as well as parents' negative emotions and infants' attention to facial expressions of emotion in a typically developing sample of 12-to-16-month-olds.

5. Conclusion

Current findings support the idea that exposure to mothers' and fathers' negative emotions may be associated with behavioral and physiological components of infants' attention to emotional facial expressions in typical development.

Funding

This research was supported by the research priority program Amsterdam Brain and Cognition, and by the Netherlands Organization for Scientific Research, NWO (VICI grant 453-09-001 to Susan M. Bögels).

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